

# Design and analysis of composite Leaf Spring for light Weight Vehicle

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**Abstract**— In recent year automobile industries are mostly concentrating on weight reduction and in improving the riding quality. To reduce vehicle weight, three techniques have been studied rationalizing the body structure, utilizing light weight materials for parts and decreasing the size of the vehicles. In this approach by introducing composite materials into automobile industries, which is having low cost, high strength to weight ratio and excellent corrosive resistance can fulfill the requirement. The suspension leaf spring is one of the potential entities for weight reduction in automobiles as it results in large unstrung mass. The introduction of fiber reinforced plastics (FRP) is used to reduce the weight of the product without any reduction on load carrying capacity and spring rate. As the materials high strain energy storage capacity and high strength-to-weight ratio compared to steel, multi-leaf springs are being replaced by mono-leaf FRP spring. FRP springs also have excellent fatigue resistance and durability.

**Keywords**— leaf spring, composites, CATIA, ANSYS, suspension system.

## I. INTRODUCTION

A suspension system is one having springs and other devices that insulate the chassis of a vehicle from shocks transmitted through the wheels.

The main components of the suspension system are:

- Struts
- Shock absorbers
- Springs
- Tires

The automobile chassis is mounted by the axles, not directly but through some form of springs. This is done to isolate the vehicle body from the road shocks which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame and body. All the part performs the function of isolating the automobile from the road shocks are collectively called a suspension system. It

also includes the spring device and various mountings. A suspension system consists of a spring and a damper. The energy of road shock causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper, which is more commonly called a shock absorber.

A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. The different types of springs are:

1. Helical springs
2. Conical and volute springs
3. Torsion and spiral springs
4. Leaf springs
5. Disc or Belleville springs
6. Special purpose spring

## II. LEAF SPRING

The leaf spring is main element of the suspension system. It can control for the wheels during acceleration, braking and turning, general movement caused by the road undulations. Leaf springs are designed in two methods: multi-leaf and mono leaf. The multi-leaf spring is made of several steel plates of different lengths stacked together. During normal operation, the spring compresses to absorb road shock. The leaf spring bends and slide on each other allowing suspension movement. An example of a mono-leaf spring is the tapered leaf spring. The leaf is thick in the middle and tapers towards the two ends. Many of these leaf springs are made of composite material, while others are made of steel. In most cases leaf springs are used in pairs mounted longitudinally (front and back). However, there is an increasing number of vehicle manufacturers using single transverse (side to side) mounted leaf spring.

Three types of leaf springs are:

1. Laminated or Multi-leaf springs.
2. Single or Mono-leaf springs.
3. Tapered leaf springs.

The third type of leaf spring is the combination of the above two. The multi-leaf springs are commonly used in the

automobile suspension system at the rear side and are still in use for commercial vehicles suspension system. It consists of a number of steel strips or leaves placed on the top of each other and then clamped together. The type of application and load carried determines the length and number of leaves. The top leaf is called as the main leaf and the ends of the leaf are rolled to form the eye of the spring. This is for attachment to the vehicle chassis or body. The spring eye allows movement about the shackle and pin at the rear.

### III. DIFFERENT TYPES OF EYES USED IN LEAF SPRING



Fig.1: Standard eye



Fig.2: Reverse eye

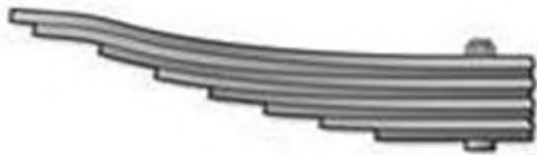


Fig.3: No eye



Fig.4: Berlin eye

### IV. COMPOSITES

A composite is usually made up of at least two materials out of which one is the binding material, also called matrix and the other is the reinforcement material (fiber Kevlar and whiskers). The advantage of composite materials over conventional materials stem largely from their higher

specific strength, stiffness, strong load carrying capacity and fatigue characteristics, which enables structural design to be more versatile.

Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material.

### V. PROPERTIES OF THE MATERIAL

Table.1: Properties of (65Si7) EN47 Steel leaf spring

Sr. No.	Parameter	Value
1	Young's Modulus E(MPa)	$2.1 \times 10^5$
2	Poisson's Ratio	0.266
3	Tensile Strength Ultimate(MPa)	1272
4	Tensile Yield Strength(MPa)	1158
5	Density(Kg/mm <sup>3</sup> )	$7.86 \times 10^{-6}$

Table.2: Properties of E-Glass/ Epoxy composite leaf spring

Sr. No.	Parameter	Value
1	Tensile Strength (MPa)	900
2	Compressive Strength (MPa)	450
3	Poisson's Ratio	0.217
4	Density (Kg/m <sup>3</sup> )	$2.16 \times 10^5$
5	Flexural modulus (E) (MPa)	40000

Table.3: Properties of S-glass/ Epoxy composite leaf spring

Sr. No.	Parameter	Value
1	Tensile Strength(MPa)	4585
2	Poisson's Ratio	0.22
3	Density (Kg/m <sup>3</sup> )	2480
4	Young's Modulus (E) (MPa)	86900

Table.4: Properties of KEVLAR composite leaf spring

Sr. No.	Parameter	Value
1	Tensile Strength(MPa)	3000
2	Poisson's Ratio	0.360
3	Density( Kg/m <sup>3</sup> )	$1.44 \times 10^3$
4	Young's Modulus (E) (MPa)	112000

**VI. DESIGN AND MODELING****Design:***Table.5: Design parameters*

Parameter	Value
Length of master leaf spring	1200mm
Free Camber	200mm
Thickness	6mm
Width	50mm

**Dimensions of the master leaf spring**

Number of graduated leaves = 6

Ineffective length = 200 mm

Length of second leaf = 1150 mm

Length of third leaf = 1000 mm

Length of fourth leaf = 700 mm

Length of fifth leaf = 580 mm

Length of sixth leaf = 430 mm

Length of seventh leaf = 300 mm

This leaf spring is used in Ambassador Car. Material used for steel leaf spring is 55 Si 2 Mn90 steel.

**Design data:**

Length of master leaf spring ( $2L_1$ ) = 1200mm

Free camber (y) = 200mm

Thickness (t) = 6mm

Width (b) = 50mm

Radius of curvature (R) =  $(L_1)^2 / 2y$   
 $= (600)^2 / 2 \times 200$

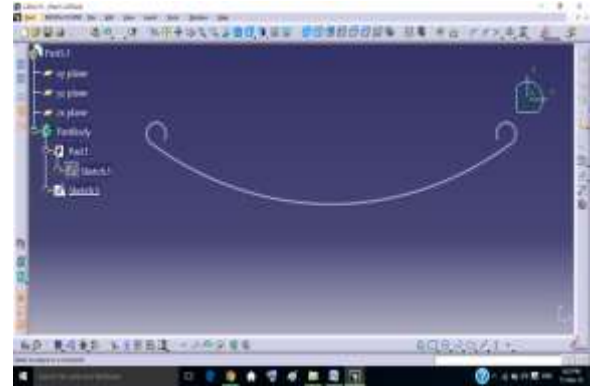
R = 900 mm

**Modeling using CATIA:**

**CATIA** is the world's leading CAD/CAM/CAE software. This software gives you a broad range of integrated solutions. CATIA is the digital product definition, simulation and manufacturing tool of choice for leading manufactures and have been for more than 20 years. Its capabilities have been shaped around the needs of leading edge companies across the aerospace, defense and automotive, industrial equipment, energy and consumer goods industry sectors.

CATIA (Computer Aided Three-Dimensional Interactive Application) started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault, at that time customer of the CAD/CAM CAD software to develop Dassault's Mirage fighter jet.

CATIA provides a wide range of applications for tooling design, for both generic tooling and mold & die. A rich catalog of industry-standard components is provided to automate tooling definition. Specific tools are also provided to address the needs of mold tool injection designers.

**Modeling:***Fig.5: leaf spring modeling***VII. PROCEDURE**

- First create the key point 100 at origin, i.e. x, y, z = (0, 0, 0).
- Create another key point 200 at some arbitrary distance in Z-direction, say x, y, z = (0, 0, 200).
- Join the above two key points 100 and 200 to get the reference axis.
- By using data from mathematical analysis Create the key point1 with a distance of radius of curvature R1 in vertically down-ward direction, i.e. x, y, z = (0, -R1, 0).
- Similarly key points 2 and 3 correspond to R2, i.e. x, y, z = (0, -R2, 0) and key points 4 and 5 corresponds to R3, i.e. x, y, z = (0, -R3, 0).
- Key point 20 corresponds to R11. i.e. x, y, z = (0, -R11, 0).
- Join the pair of key points sequentially as follows Key points 1 and 2, 2 and 3, 3 and 4...and 19 and 20.
- Then line1 formed by the key points 1 and 2, line2 formed by the key points 2 and 3 and line10 formed by the key points 19 and 20.
- Extrude the above lines with respect to reference axis stated in step3 as follows:
  - Extrude line1 with an angle  $\Phi_1$ , will get area1
  - Extrude line2 with an angle  $\Phi_2$ , will get area2,.....and
  - Extrude line10 with an angle  $\Phi_{10}$ , will get area10.
- Extruding all the lines, the semi area of the spring without eye will form on XY- plane with significant degeneracy.
- To avoid degeneracy, extend the right side line of smallest area i.e. area 10 to some extent such that it cross the top most area i.e. area1. Now divide area by line. For this, select the areas left to extended line1 and divide with that line. Similarly, extend the right side

line of second smallest area i.e. area9 to some extent such that it cross the top most area i.e. area1. Again divide area by line. For this select the areas left to extended line2 and divide with that line.

- The above process is to be done up to extension of line of area9 and divide area by extension line9.
- Now perfect half area of leaf spring without eye will form.
- Eye construction:

Extend the right side line of top most area i.e. area1 to the length equal to the radius of eye. Delete lines only, so that key point of that line will remain. Shift the origin to that key point. Create another key point say some key point300 in Z-direction. Join the above two key points to get reference axis to rotate the right side line of area1. Extrude the line with respect to reference axis to an angle  $275^{\circ}$  to  $280^{\circ}$ . Delete all reference lines. So, half area of leaf spring with eye is formed.

- To get the full area of the leaf spring. Shift the origin to the top left most area key point i.e. key point1. Reflect the entire area with respect to YZ – plane.
- To get the solid model of the leaf spring, extrude the area by Z-offset to a length equal to the width of the leaf spring.
- To make a cylindrical hole at centre of the leaf spring to provide bolting for all the leaves, so that all the leaves are in perfect alignment: Create centre key point of the leaf spring on the top view i.e. XY-plane, by using key points between key points' command. Shift the origin to that key point. Choose the proper work plane by using work plane Create a cylinder along Z-axis in vertically downward direction. Subtract the cylinder from the solid leaf spring. So that leaf spring with hole to provide bolt will obtain. The models are presented in the below figures.

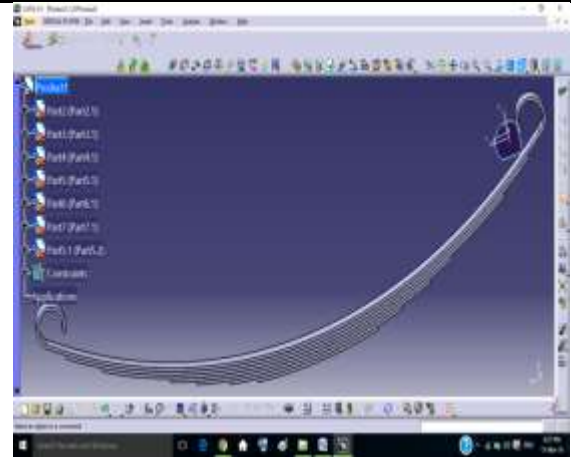


Fig.6: leaf spring

## VIII. ANALYSIS OF THE LEAF SPRING

ANSYS finite element analysis (FEA) is a computer based numerical technique for calculating the strength and behavior of engineering structures. It can be used to calculate deflection, stress, vibration, buckling behavior and many other phenomena. It can be used to analyze either small or large-scale deflection under loading or applied displacement. It can analyze elastic deformation, or permanently bent out of shape plastic deformation. The computer is required because of the astronomical number of calculations needed to analyze a large structure. The power and low cost of modern computers has made Finite Element Analysis available to many disciplines and companies.

Methodology:

- Finite element model is prepared on CAD geometry.
- Hyper mesh software used to create mesh.
- Hexahedral mesh done on leaf spring geometry.
- Then deck is prepared
- Deck preparation steps –
  - 1) Apply material properties.
  - 2) Apply boundary conditions.
  - 3) Apply load.
  - 4) Export deck as \*.inp file.

## IX. MESHING



Fig.7: meshing



## X. RESULTS

Analytical design and calculations of the composite leaf spring are shown according to their varying loads. In this project we are applying loads from 1000N to 4000N. Each load is applied to the composite materials which are tested. In each load the composite materials which we applied is shown with total deformation and equivalent stresses of the each composite material.

The results of the each material with the load of 1000N are shown with the total deformation and equivalent stresses in the below table.

Table.6: Details for load 1000N

Sr. No.	Material	Total Deformation, (mm)	Equivalent stresses (MPa)
1	AL Si 6150 Steel	0.88264	65.804
2	Ti 6A14V Alloy	1.7218	65.732
3	65 Si7 EN47	0.86242	66.065
4	Carbon Epoxy	1.0231	66.023
5	EN47 Steel	0.90604	66.227
6	Kevlar	1.6101	66.493
7	S-Glass Fiber	2.0871	66.502
8	E Glass Epoxy	5.3349	66.528

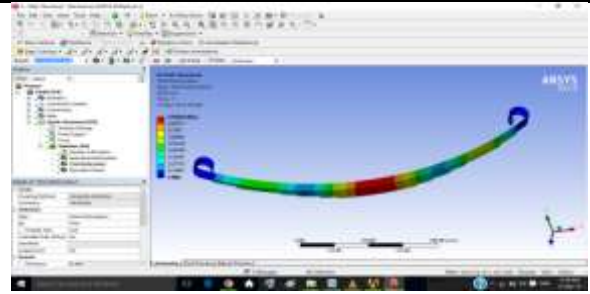


Fig.10: Total deformation of EN47 steel

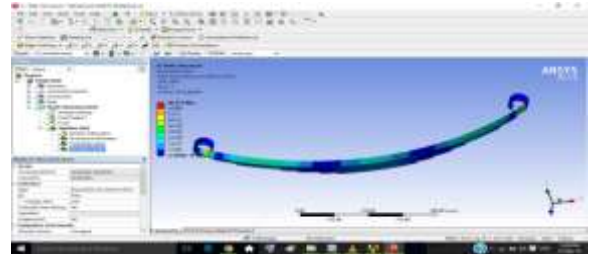


Fig.11: Equivalent stress for EN47 steel

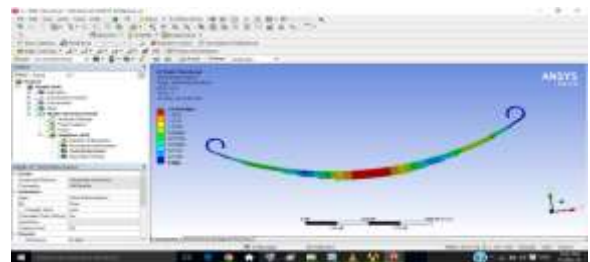


Fig.12: Total deformation of Kevlar



Fig.13: Equivalent stress for Kevlar



Fig.8: Total deformation of E-glass epoxy

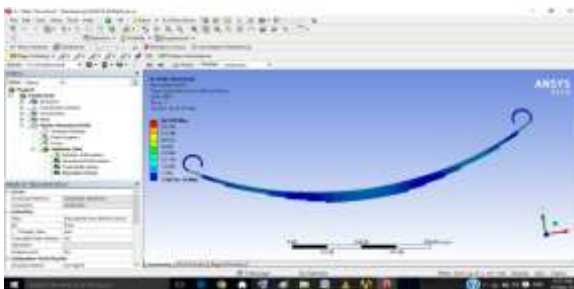


Fig.9: Equivalent stress for E-glass epoxy

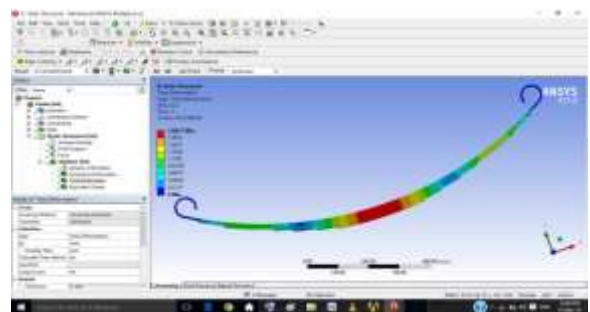


Fig.14: Total deformation of S-glass

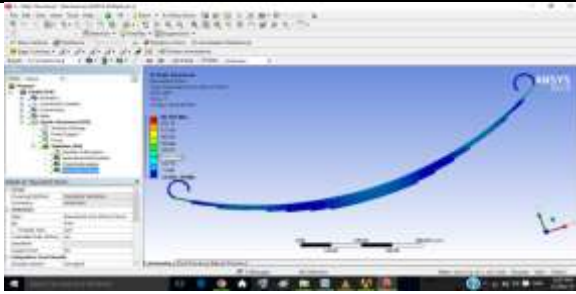


Fig.15: Equivalent stress for S-glass

## XI. CONCLUSION

As automobile world demands research of reducing weight and increasing strength of products, composite material should be up to the mark of satisfying these demands. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, we introducing Kevlar material which is least in weight and bears more load with less deformation when compared to other materials.

The results of static analysis of both steel and composite leaf springs like EN47, KEVLAR, S-Glass Epoxy & E-Glass Epoxy are discussed in this chapter. Thus by comparing the above results we can say that Kevlar material is better than conventional steel, E-Glass/Epoxy, S-Glass Epoxy and the other composite materials. The total deformation and the Equivalent stresses for the Kevlar are shown in the table below.

Table.7: Total Deformation and Equivalent Stresses at Variable Load Conditions

S. No	Load, (N)	Total Deformation,(mm)	Equivalent Stresses, (MPa)
1	1000	1.6101	66.49
2	2000	3.2202	132.99
3	3000	4.8302	199.48
4	4000	6.4403	265.97

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